THE PROBLEM OF ALIEN IMMIGRATION INTO GREAT BRITAIN, ILLUSTRATED BY AN EXAMINATION OF RUSSIAN AND POLISH JEWISH CHILDREN.

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PART III.

CONTENTS.

D. *The Influence of Ocular Characters on Intelligence.* It is not infrequently supposed that the school work of children is badly handicapped, and that the teachers' judgment of their intelligence is greatly influenced by the child's poor sight. Our data enable us to consider to some extent both these suppositions.

(i) *Place in Class and Visual Acuity.* We have the place in class recorded of 345 boys who were submitted to the special eye examination. Table CCXXXVI contains the results.

Table CCXXXVI. *Place in Class and Binocular Visual Acuity (Boys).*

Visual Acuity (Binocular)	Place in Class. 1–2	3–4	5–6	7–8	9–10	11–12	13–14	15–16	17–18	19–20	21–22	23–24	25–26	27–28	29–30	31–32	33–34	35–36	37–38	39–40	41–42	43–44	45–46	47–48	49–50	Totals
1·50	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	3
1·40	—	—	1	1	1	—	1	—	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	6
1·29	2	1	—	2	3	1	4	3	—	3	2	3	4	3	1	—	3	3	5	1	3	1	—	1	—	49
1·11	4	4	3	6	3	5	9	4	7	6	4	3	4	1	2	5	5	4	4	3	3	3	3	2	1	98
·91	4	3	5	2	6	2	6	5	6	4	2	7	2	1	2	4	3	3	3	2	1	6	3	2	3	87
·75	1	4	—	3	1	2	4	—	2	—	2	—	1	1	3	3	2	—	1	2	—	1	2	—	—	35
·58	—	—	1	—	2	1	2	1	1	1	1	4	1	2	—	—	1	1	1	—	3	—	—	1	2	26
·37	1	—	—	—	1	2	—	1	—	1	1	1	1	—	1	4	—	1	1	1	1	—	—	—	—	18
·25	—	—	—	1	1	1	—	—	—	—	—	—	—	—	—	2	—	—	—	—	1	1	—	—	—	7
·14	2	—	—	1	—	2	1	1	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	9
·08	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	1	—	—	—	4
·04	—	—	—	1	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	3
Totals	14	12	10	18	18	16	27	15	16	17	13	19	13	10	10	18	15	12	18	9	12	13	8	6	6	345

The product moment value of the correlation coefficient on this table is $+ \cdot 0065 \pm \cdot 0363$, better vision being associated with *lower* place in class. But the correlation is far less than its probable error, and is thus insignificant. What is more, such as it is, the boys towards the top of the class have the worse sight.

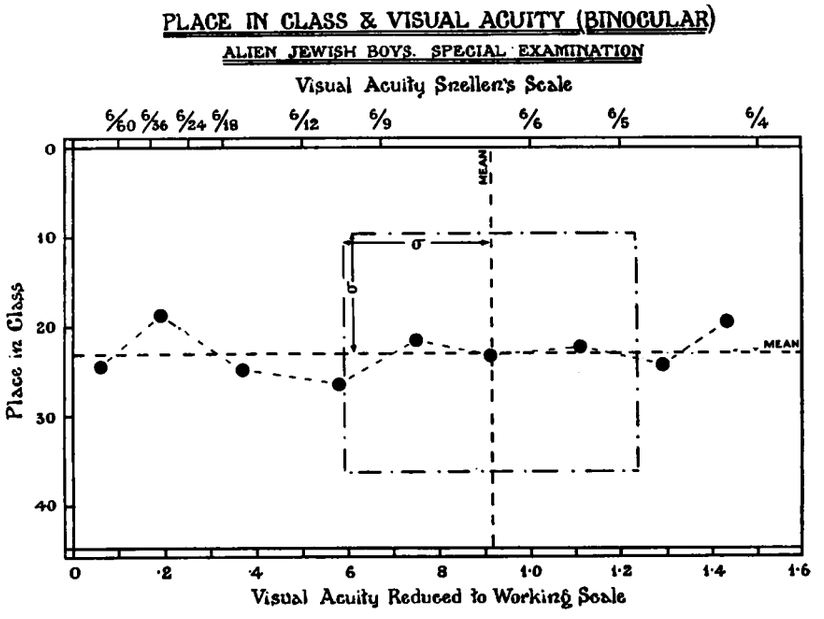

Diagram 118.

(ii) *Intelligence and Visual Acuity.* We can now test visual acuity against intelligence. This has been tabled for both monocular and binocular vision.

Tables CCXXXVII and CCXXXVIII. *Intelligence and Visual Acuity* (*Boys*).

Vision	Monocular Vision						Totals	Binocular Vision						Totals
	Very Able	Capable	Intelligent	Slow Intelligent	Dull	Very Dull		Very Able	Capable	Intelligent	Slow Intelligent	Dull	Very Dull	
1·50	—	—	3	—	—	—	3	—	—	3	—	—	—	3
1·40	3	—	9	3	2	—	17	—	—	5	1	1	—	7
1·29	1	11	28	40	5	—	85	1	6	22	29	6	—	64
1·11	6	14	87	67	19	3	196	4	8	56	44	11	3	126
·91	6	22	94	90	25	2	239	1	12	40	36	14	1	104
·75	2	11	43	42	14	2	114	2	4	13	19	3	—	41
·58	1	5	39	49	13	2	109	—	3	15	12	6	1	37
·37	3	8	34	38	9	4	96	—	4	9	10	2	1	26
·25	3	11	14	15	5	1	49	—	2	3	4	2	—	11
·14	4	6	21	14	5	—	50	2	—	5	2	1	—	10
·08	1	2	7	5	3	—	18	—	1	1	3	1	—	6
·04	—	—	7	9	2	—	18	—	—	2	2	—	—	4
Totals	30	90	386	372	102	14	994	10	40	174	162	47	6	439

We have the following results:

Monocular Vision	Binocular Vision
$\eta'^2_{V.I} = ·004{,}243$	$\eta'^2_{V.I} = ·005{,}854$
$\bar{\eta}^2_{V.I} = ·005{,}030$	$\bar{\eta}^2_{V.I} = ·011{,}389$
$\eta'^2_{I.V} = ·016{,}227$	$\eta'^2_{I.V} = ·003{,}438$
$\bar{\eta}^2_{I.V} = ·007{,}042 \pm ·002{,}521$	$\bar{\eta}^2_{I.V} = ·013{,}687$

It is clear that in three out of the four cases η'^2 is less than $\bar{\eta}^2$ and is therefore insignificant.

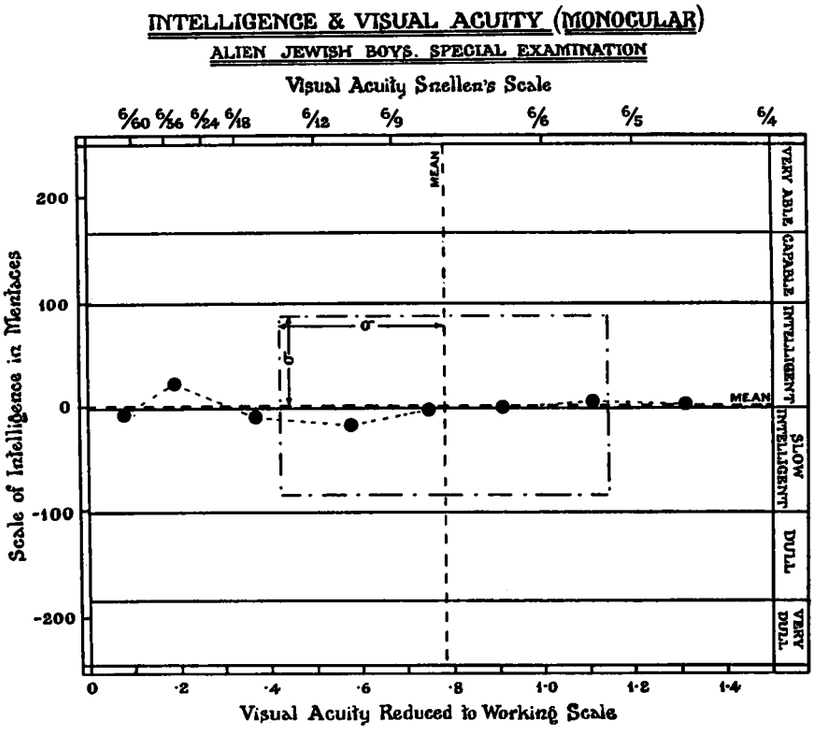

Diagram 119.

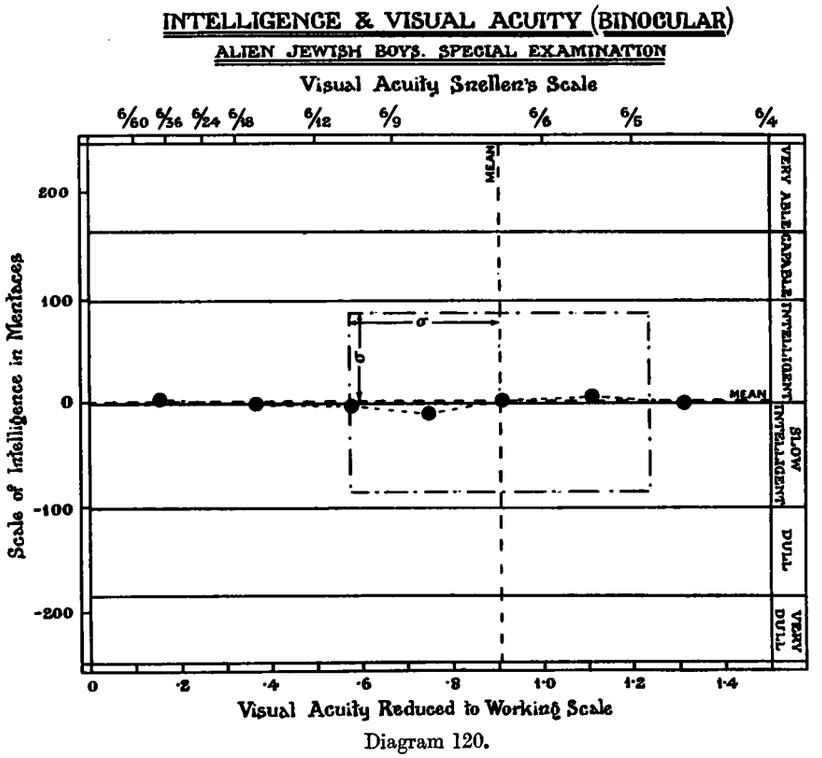

Diagram 120.

In the fourth case $\eta'^2_{I.V} - \bar{\eta}^2_{I.V}$ is 3·6 times the probable error and therefore some stress may be laid upon it.

Investigating this point further we have the following degrees of intelligence for each monocular vision class given in the first column, measuring as usual intelligence from the mean of the population and taking the range of "Intelligent" as 100 mentaces:

Visual Acuity	Intelligence in Excess of Mean
1·31 or 6/4·6 Snellen	+2·777 ±5·428 mentaces
1·11 „ 6/5·4 „	+6·470 ±4·035 „
·91 „ 6/6·6 „	−0·335 ±3·654 „
·75 „ 6/8·0 „	−4·363 ±5·290 „
·55 „ 6/10·1 „	−18·491 ±5·410 „
·37 „ 6/16·2 „	−9·472 ±5·765 „
·19 „ 6/31·5 „	+23·306 ±5·677 „
·06 „ 3/500 „	−7·805 ±9·414 „

The only two intelligence deviations which are significant, having regard to their probable errors*, are those for visions of ·55 and ·19; these are both low visual acuities, but the intelligence of the first is in defect and of the second in excess. There is no regular order in these means, and all we can say is that there appears to be a small group of boys—not in the case of binocular, but in that of monocular vision—who had a worse vision and a rather higher average intelligence than the general population. The average of this low visioned class is about 30 mentaces, i.e. less than a third up the total range of "Intelligent" from the border line of "Intelligent" and "Slow Intelligent." We shall see later that in the medical examination there seems to be no sign of this group. But as we shall see under the heading of refraction class later, there is some evidence for a group of myopes with intelligence above the average, just as there is an excess of myopes among the "Slow."

Finally testing what this small group may mean by a correlation coefficient based upon the quantitative visual acuity and a normal intelligence scale, we find:

$$r = + \cdot0093 \pm \cdot0214,$$

which is of no significance. It does not accordingly seem possible to deduce any result indicating that the children with poorer vision are the less intelligent.

These results seem so opposed to the current opinion that stupidity and backwardness in children—which weigh heavily in teachers' estimates—are due frequently to defective sight, that we determined to test the whole matter once more on the independent testing of vision by the Medical Examiners. Of the children thus tested we found 572 boys and 527 girls were included in our records of intelligence.

Tables CCXXXIX and CCXL. *Visual Acuity (Better Eye) and Intelligence.*

	Boys								*Girls*							
Intelligence	Visual Acuity							Totals	Visual Acuity							Totals
	1·16	·84	·57	·37	·25	·18	·10		1·16	·84	·57	·37	·25	·18	·10	
V. Able	5	3	5	1	1	1	—	16	2	2	1	1	1	—	—	7
Capable	28	17	13	9	6	—	1	74	9	10	9	2	4	—	—	34
Intelligent	72	54	44	24	6	10	2	212	33	39	30	25	4	3	—	134
Slow Intelligent	53	66	35	19	11	8	5	197	37	64	54	26	12	8	1	202
Dull	17	22	14	6	4	1	—	64	18	34	21	13	6	2	1	95
Very Dull and M.D.	1	3	3	1	—	—	1	9	8	16	16	7	1	6	1	55
Totals	176	165	114	60	28	20	9	572	107	165	131	74	28	19	3	527

* Calculated from the formula ·67449 S.D./$\sqrt{\text{number}}$, the S.D. being that of the whole intelligence distribution = 83·745 mentaces. Thus the values are only approximate.

These lead to the following results:

	Boys	*Girls*
$\eta'^2_{I.V}$	= ·024,086	·019,451
$\bar{\eta}^2_{I.V}$	= ·008,741	·009,488
P.E. of $\bar{\eta}^2_{I.V}$	= ·003,712	·004,021

Thus the difference of the two η^2's is 4·1 times the probable error for boys and under 2·5 times the probable error for girls. Assuming that these values may be significant—they correspond to values uncorrected for class index of $\eta' = ·1552$ and ·1395 respectively—we have pursued the matter further by determining the mean values of intelligence for each acuity of vision class in mentaces* measured from the mean intelligence.

Vision Class	Deviation from Mean Intelligence	
	Boys	*Girls*
1·16	+15·80 ± 4·73	+18·62 ± 6·61
·84	−18·09 ± 4·88	− 6·60 ± 5·33
·57	+ 4·24 ± 5·87	− 4·35 ± 5·98
·37	+ 9·15 ± 8·10	+ 9·22 ± 7·95
·25	−20·64 ±11·85	+ 1·95 ±12·93
·16	− 8·64 ±11·64	−48·75 ±14·59
General Population	0·00 ± 2·62	0·00 ± 2·98

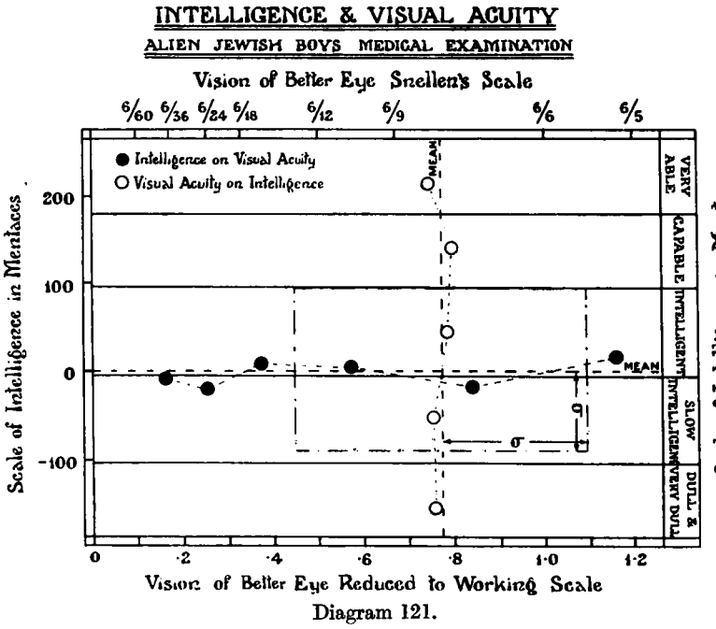

Diagram 121.

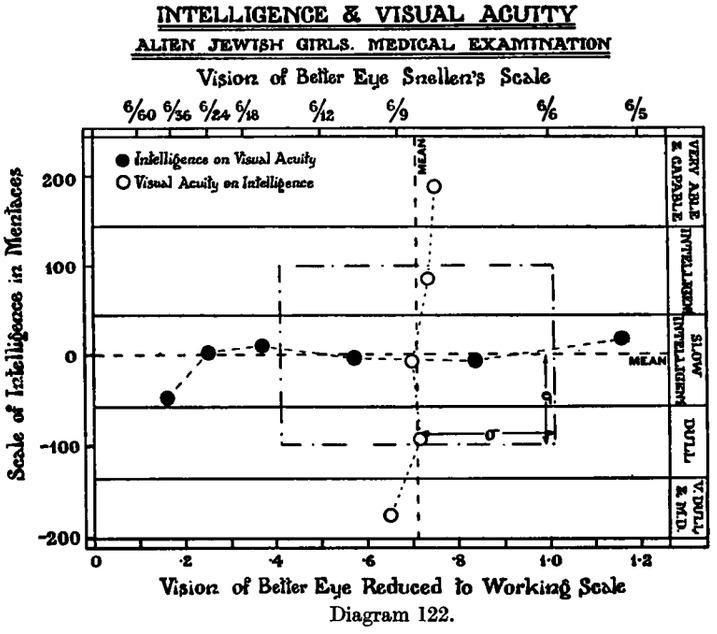

Diagram 122.

These means do not seem to indicate any orderly change of intelligence with acuity of vision. This the reader will grasp if he examines Diagrams 121 and 122. Very good sight may have slightly more intelligence, and very bad sight—at any rate in the case of the Girls—may have

* The range of the Intelligent group is taken as 100 mentaces. σ = 92·97 mentaces for the Boys and 101·43 for the Girls. From the border line of Intelligent and Slow the mean is + 6·52 mentaces for Boys and − 44·04 mentaces for the Girls.

slightly less intelligence*. We may again turn the question round and ask what grade of vision is associated with each grade of intelligence. We find:

Grade of Intelligence	Mean Acuity of Vision	
	Boys	*Girls*
Very Able	·748	·741
Capable	·799	·756
Intelligent	·785	·738
Slow Intelligent	·754	·701
Dull	·775	·718
Very Dull and M.D. ...	·651	·652
General Population	·772	·713
Standard Deviation of Vision	·3247	·3017

There seems very little association in the case of Boys, but more appreciable results in the case of Girls. Applying the test of the correlation ratio we find:

$$\eta'^2_{V.I} = \cdot 004{,}862 \text{ for Boys}, \quad = \cdot 009{,}441 \text{ for Girls.}$$
$$\bar{\eta}^2_{V.I} = \cdot 008{,}741 \quad ,, \quad = \cdot 009{,}488 \quad ,,$$

Thus by this test neither is significant. If they be treated as significant, we should have

$$\eta'_{V.I} = \cdot 0697 \text{ for Boys}, \quad = \cdot 0972 \text{ for Girls.}$$

These values are less than we have found for Intelligence on Vision, and of little importance in themselves. Finally we determined the correlation coefficient using the mean of the intelligence groups and the means of the vision arrays given above. This led to the values:

$$\textit{Boys:}\ r = \cdot 0420 \pm \cdot 0282, \qquad \textit{Girls:}\ r = \cdot 0801 \pm \cdot 0292.$$

Summing up we find that there is very little influence of acuity of vision on intelligence in Boys, there appears to be a certain small amount in Girls, but we believe its source to be that this acuity of vision in the medical examination is usually taken by the nurse; and that the examination is too quick in a subjective test to allow a stupid child really providing what it can only be led up to slowly and cautiously. Consequently the Girls, whom we have shown to have a far lower standard of intelligence than the Boys, exhibit a higher association between acuity of vision and intelligence. The relationship is after all not of importance, but we believe that the apparent vision follows the dulness, and not the dulness the poorer vision.

(iii) *Position of Near Point and Intelligence.* We have already seen that our observations on the near point are not in accordance with current statements; we find that the near point has increasing distance from 8 to 10·5 years and then gets closer for 10·5 to 15 years; the changes with age are, however, slender, and we have not thought it needful to correct the near point for age, when correlating it with other characters†.

We have endeavoured to find the relation between the Distance of Near Point and Intelligence. We shall first contract Table CCXLI and study the $\eta'_{I.NP}$. This is done in Table CCXLII and we find:

$$\eta'^2_{I.NP} = \cdot 014{,}921,$$
$$\bar{\eta}^2_{I.NP} = \cdot 011{,}873 \pm \cdot 003{,}750.$$

* The last group of worst vision is, however, based only on 29 cases for the Boys and 22 for the Girls.

† The correlation of Intelligence and Age being sensibly zero and that of Age and the Distance of Near Point of order $-\cdot 1$, it is clear that multiplying by the factor 1·005 will not sensibly modify the correlation of Intelligence and Distance of Near Point, i.e. ·1250.

Table CCXLI. *Intelligence and Distance of Near Point (Boys).*

Distance of Near Point in mm.

Intelligence	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115
Very Able	—	—	—	—	—	1	—	2	—	3	2	—	2	2	—	—	1
Capable	—	—	2	1	1	1	4	6	5	7	6	11	8	—	6	3	2
Intelligent	1	—	—	—	1	6	12·5	18·5	15·5	35·5	34	32	37	27	16	15	11
Slow Intelligent	—	—	—	—	3	5	5	17	21	29	28	42	29	29	16	15	11
Dull	—	—	—	1	1	1	3	4	9	12	10	11	8	6	2	2	2
Very Dull and M.D.	—	—	—	—	1	1	—	—	—	2	—	3	1	1	2	—	1
Totals	1	—	2	2	7	15	24·5	47·5	50·5	88·5	80	99	85	65	42	35	28

Distance of Near Point in mm.

Intelligence	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	Totals
Very Able	1	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	16
Capable	2	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	68
Intelligent	7	6	9	6	1	4	2	—	1	—	1	—	1	—	—	—	—	300
Slow Intelligent	5	6	8	7	5	1	2	—	—	—	—	—	—	—	—	—	—	284
Dull	2	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	78
Very Dull and M.D.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12
Totals	17	13	20	16	7	5	4	—	1	—	1	—	1	—	—	—	1	758

We cannot therefore assert that the correlation ratio differs significantly from its value for no association.

Table CCXLII. *Contracted Table for Intelligence and Distance of Near Point.*

Distance of Near Point Central values in mm.	Intelligence: Very Able and Capable	Intelligent	Slow, Dull, etc.	Totals
60·24	10	20·5	21	51·5
72·5	13	34	51	98
80	10	35·5	43	88·5
85	8	34	38	80
90	11	32	56	99
95	10	37	38	85
102·5	8	43	56	107
112·5	6	26	31	63
125	5	22	23	50
143·75	3	16	17	36
Totals	84	300	374	758

Diagram 123 gives the result of intelligence plotted for each value of near point distance. It is clear that there is a very small relation between the two variates. Those with the nearest near point are the least intelligent, and although the last two groups show more intelligence, the group with near point of 90 mm. is the most intelligent of the whole series*. The correlation deduced from the means of the intelligence groups of the above table and the central values of the near point distances is $r = \cdot1250$ and biserial r found from the long table, the division being

* Mean Near Point Distance = 93·008 mm., Standard Deviation = 19·7481, Intelligent group range = 100 mentaces, Standard Deviation of Intelligence σ_I is given by $1\cdot2387\sigma_I = 100$ mentaces, or $\sigma_I = 80\cdot73$ mentaces.

made between Intelligent and Slow, is $r = \cdot1244$, in good agreement. But alas! when we came to apply the fourfold table method we made the two following divisions:

N.P. Distance	Intelligent	Dull	Totals	N.P. Distance	Intelligent	Dull	Totals
<95	208	209	417	<90	165	153	318
95 and over	176	165	341	90 and over	219	221	440
Totals	384	374	758	Totals	384	374	758

and found that the first of these fourfold tables gave a small correlation, between dulness and a small near point distance, while the second gave a small correlation between dulness and a large near point distance, both however non-significant*. The correlation is swung over in sign by the group into which we put the individuals with a near point of 90 mm.—a group on which we have already commented. The fact is one which cannot be too often emphasised, namely, that when the correlation is small, it is not possible without extremely large numbers to obtain consistent results by applying methods which depend on the hypothesis of a definite form of frequency. All we can conclude is that the correlation is not large enough to give even approximately consistent results, and also is not large enough to be of any significance for the purposes of school hygiene.

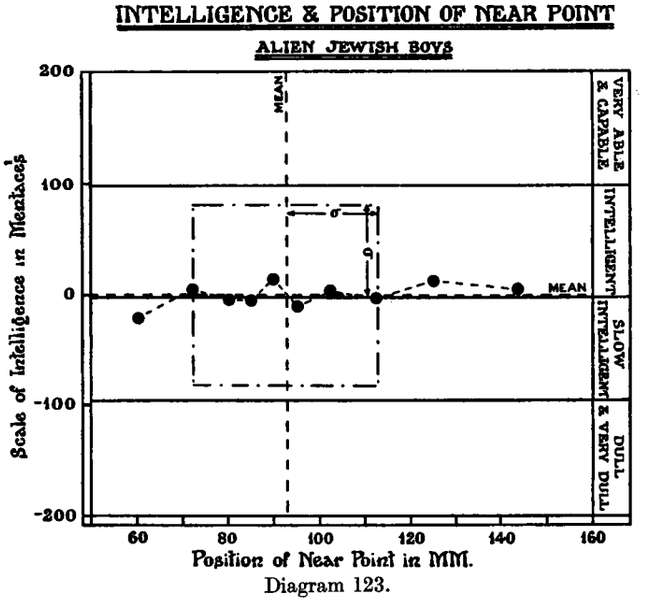

Diagram 123.

Some further light is thrown on the source of this inconsistency if we look at the matter from the reverse standpoint and ask what are the near point distances for different grades of intelligence. We have

Intelligence Grade	Mean Distance of Near Point
Very Able and Capable	89·5833 mm. ±1·4533
Intelligent	94·1167 „ ± ·7690
Slow—Intelligent	94·2430 „ ± ·7903
Dull and Very Dull	88·5556 „ ±1·4041
General Population	93·0079 „ ± ·4838

From this it appears that the regression of near point distance on intelligence is skew, and that in fact the Dull and Very Dull have the closest near points†. We find:

$$\eta'^2_{NP.I} = \cdot012{,}081, \text{ while } \bar{\eta}^2_{NP.I} = \cdot003{,}958 \pm \cdot002{,}174.$$

Thus $\eta'_{NP.I}$ seems likely to be significant, but it corresponds only to a value of $\eta'_{NP.I}$ of ·1099,

* We have $r_{t_1} = -\cdot0272 \pm \cdot0386$, $r_{t_2} = +\cdot0330 \pm \cdot0387$ for the tetrachoric correlations of the first and second tables respectively.

† The reader must bear in mind that the Standard Deviation of the near point distance is 19·7481 mm. and accordingly the above differences in the group means are really small, their deviations from the mean of the general population are hardly significant, having regard to their probable errors.

which correction for class index would raise to about ·12. The fact that this small association is skew or that we are dealing with two variates which do not change continuously in one direction, the one with the other, leads us again to the conclusion, that it is not the position of the near point which influences intelligence.

(iv) *Position of the Near Point and Place in Class.* Finally we are able to throw further light on the matter by correlating place in class with near point distance.

Table CCXLIII. *Distance of Near Point and Place in Class.*

Distance of Near Point in mm.

Place in Class	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	..	180	..	200	Totals
1–2	—	—	—	1	—	3	2	8	1	—	4	1	1	3	1	1	—	—	—	—	—	—	—	—	..	—	..	—	26
3–4	2	1	1	—	1	2	—	3	3	4	1	2	—	—	—	—	1	—	—	—	—	—	—	—	..	—	..	1	22
5–6	—	—	1	1	2	2	—	3	2	1	1	—	2	2	1	—	—	1	—	—	—	1	—	—	..	—	..	—	20
7–8	—	—	—	—	—	4	1	4	4	8	4	5	—	—	2	—	1	—	—	1	—	—	—	—	..	—	..	—	34
9–10	—	—	—	3	—	3	3	3	4	4	4	2	1	2	1	2	1	—	1	—	—	—	—	—	..	—	..	—	34
11–12	—	—	—	2	3	2	1	1	3	2	3	3	4	1	—	—	1	2	—	—	—	—	—	—	..	—	..	—	28
13–14	—	—	—	—	4	1	3·5	3·5	8	7	3	4	2	—	1	2	1	2	—	2	—	—	—	—	..	—	..	—	44
15–16	—	—	—	1	2	2	2	2	3	3	4	2	1	1	1	—	—	1	1	—	—	—	—	—	..	—	..	—	26
17–18	—	—	—	—	—	—	1	3	6	4	2	1	4	5	1	1	—	1	—	1	—	—	—	—	..	—	..	—	30
19–20	—	—	1	1	1	3	—	4	1	7	3	1	1	—	3	1	—	—	1	—	2	—	—	—	..	—	..	—	30
21–22	—	—	—	—	—	1	3	2	1	3	3	1	4	—	1	—	—	—	1	—	—	—	—	—	..	—	..	—	20
23–24	—	—	—	—	—	1	2	6	3	—	2	3	2	2	1	1	—	2	2	1	—	—	—	—	..	—	..	—	28
25–26	—	—	—	—	1	—	1	—	6	9	2	1	—	—	2	1	—	—	—	—	—	1	—	—	..	—	..	—	24
27–28	[1 at 35]			—	1	1	—	—	3	1	2	3	2	—	—	—	—	—	2	—	2	—	—	—	..	—	..	—	18
29–30	—	—	—	—	1	—	1	—	—	3	5	1	2	—	1	—	—	—	—	—	—	—	—	—	..	—	..	—	14
31–32	—	—	—	2	2	4	4	—	—	2	6	—	—	—	2	—	—	—	—	—	—	—	—	—	..	—	..	—	22
33–34	—	—	—	2	1	—	2	3	6	—	4	3	1	1	—	—	1	3	1	—	—	—	—	1	..	1	..	—	30
35–36	—	—	—	—	—	—	—	3	1	3	5	5	3	2	2	—	—	—	—	—	—	—	—	—	..	—	..	—	24
37–38	—	—	—	—	—	3	4	6	3	2	2	4	—	1	—	1	—	2	—	1	—	1	—	—	..	—	..	—	30
39–40	—	—	—	—	—	—	—	2	4	7	1	1	—	—	1	1	1	—	—	—	—	—	—	—	..	—	..	—	18
41–42	—	—	—	—	1	2	1	1	—	2	2	2	—	1	—	2	2	—	2	—	—	—	—	—	..	—	..	—	18
43–44	—	—	—	—	—	4	1	7	1	4	4	1	1	1	—	—	—	—	—	—	—	—	—	—	..	—	..	—	24
45–46	—	—	1	2	—	—	1	5	—	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	..	—	..	—	12
47–48	—	—	—	—	—	—	—	4	2	1	—	—	—	1	—	1	—	—	1	—	—	—	—	—	..	—	..	—	10
49–50	—	—	—	—	—	—	1	1	2	—	2	1	—	2	—	—	—	1	—	—	—	—	—	—	..	—	..	—	10
Totals [1 at 35]	2	1	4	15	20	38	34·5	74·5	67	78	69	49	31	25	21	14	9	15	12	6	4	3	—	1	..	1	..	1	596

	Near Point Distance	Place in Class
Mean	92·5797 mm.	22·7081.
Standard Deviation	19·9875 mm.	13·4236.

Coefficient of correlation: $r = \cdot 0479 \pm \cdot 0276$.

Hence since both variates are quantitative we can obtain a straightforward product moment correlation and we see that having regard to its probable error it is insignificant. At the same time, as the accompanying figures and Diagram 124 indicate, the two lowest grades of near point distance show the highest mean places in class; the bulk of near point distance grades show, however, no association whatever with place in class.

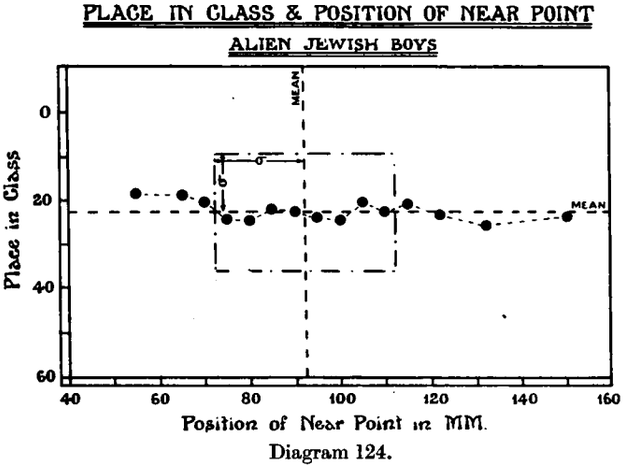

Diagram 124.

Mean Places in Class for Given Near Point.

Near Point Distance

	55·3	65	70	75	80	85	90	95	100	105	110	115	122·0	132·2	150·6
Mean Place	18·54	18·70	20·39	24·22	24·51	22·04	22·68	23·91	24·19	20·34	22·78	20·74	23·59	25·65	21·63

It would, we think, be of interest to test the ablest boys in schools and see if their near points are closer than those of less emphatic ability. In our data the boys occupying the first six places in classes of 50 have a mean near point distance of 87·87 mm., while the population mean is 92·58.

On the whole our data do not indicate that the position of the near point has any association of importance either with intelligence or its closely correlated product place in class.

(v) *Intelligence and Refraction Class.* Here we have to deal with qualitative classes in both variates and as usual the problem will be how to reach some measure of the association. Our data are given in Table CCXLIV where we have arranged our refraction classes according to the order of the percentages they provide of the three highest grades of intelligence.

Table CCXLIV. *Refraction Class and Intelligence.*

Refraction Class

Intelligence Grade	Hypermetropia	Hypermetropic Astigmatism	Emmetropia	Myopia	Myopic Astigmatism	Mixed Astigmatism	Totals
Very Able ...	—	3	17	4	—	—	24
Capable ...	7	11	37	14	5	—	74
Intelligent ...	33	22	229	51	11	4	350
Slow Intelligent ...	25	29	199	65	18	4	340
Dull	3	—	65	6	5	3	82
Very Dull ...	—	1	8	2	—	1	12
Totals	68	66	555	142	39	12	882
Percentage Intelligent Classes	58·82	54·55	50·99	48·60	41·03	33·33	50·79
Percentage Slow, Dull Classes ...	41·17	45·46	49·01	51·41	58·97	66·66	49·21

If we judge by the percentages we see that those with hypermetropia or hypermetropic astigmatism have the highest percentage of intelligence, the emmetropic group has almost exactly the mean of the general population, while the myopic and those with myopic astigmatism or with mixed astigmatism have less than the average amount of intelligence. But while these results seem so orderly and convincing when we treat percentages of the first three grades of intelligence, they are upset if we take only the two highest grades, the very able and the capable. In this case the following is the order:

Refraction Classes

	Hypermetropic Astigmatism	Myopic Astigmatism	Myopia	Hypermetropia	Emmetropia	Mixed Astigmatism
Very Able and Capable	21·22	12·82	12·68	10·29	9·37	0·00

While in the former distribution it was the weak-muscled myopes who showed the least intelligence, in the present distribution, wherein we confine our attention to the highest intelligence grades we find after those with hypermetropic astigmatism, it is the myopic classes who have most intelligence. For the present division we should obtain the highest association by dividing into i.e. emmetropia

and ametropia, including in the latter class both hypermetropic and myopic. We worked three tetrachoric tables, namely:

A. Refraction Class

	Emmetropia	Ametropia	Totals
Very Able and Capable	54	44	98
Intelligent — Very Dull	501	283	784
Totals	555	327	882

B. Refraction Class

	Emmetropia	Ametropia	Totals
Very Able, Capable, and Intelligent ...	283	165	448
Slow, Dull, and Very Dull	272	162	434
Totals	555	327	882

C. Refraction Class

	Emmetropic, Hypermetropic, Hypermetropic Astigmatism	Myopia, Myopic and Mixed Astigmatism	Totals
Very Able, Capable, and Intelligent	359	89	448
Slow, Dull, and Very Dull ...	330	104	434
Totals	689	193	882

We find for tetrachoric r_t in the three cases:

A: $r_t = -\cdot1197 \pm \cdot0477$. B: $r_t = +\cdot0083 \pm \cdot0364$. C: $r_t = +\cdot1200 \pm \cdot0395$.

The first of these, A, is negative and about 2·5 times its probable error; B gives a very small and non-significant correlation; while C gives a small correlation about three times its probable error. The first and last are probably significant, although they give opposite signs. We accordingly are driven to the conclusion that we are not dealing with a simple force acting only in one sense, but rather with compound causes to some extent of conflicting character. Taking a broad measure of intelligence the hypermetropic and emmetropic are the more intelligent, the myopic the slower and duller. This may mean that the less muscular and more "flabby" throughout are the less fit physically and less fit also intellectually. On the other hand, if we narrow our idea of intelligence to the higher grades, i.e. to 10 % or 11 % of the whole school population, we find that the myopic have a higher percentage of these grades than the normal. Here there is a possibility of a double explanation, it may mean that the studious pursuits of the more intelligent tend to produce myopic conditions, or it may signify that the less muscular and more flabby, being largely denied success in physical pursuits, seek compensation in intellectual work. We shall endeavour shortly to throw further light on this matter. What we have shown thus far is that there is a relation between Refraction and Intelligence, not a very intense one, but one of a compound and rather complicated nature. The full measure of this association is given by the coefficient of mean

Table CCXLV. *Contingency Table for Refraction Class and Intelligence.*

Refraction Class

	Hypermetropia	Hypermetropic Astigmatism	Emmetropia	Myopia	Myopic Astigmatism	Mixed Astigmatism	Totals
Very Able and Capable	7	14	54	18	5	0	98
	{− ·556}	{+6·667}	{− 7·667}	{+ 2·222}	{+ ·667}	{−1·333}	
Intelligent	33	22	229	51	11	4	350
	{+6·016}	{−4·190}	{+ 8·762}	{− 5·349}	{−4·476}	{− ·762}	
Slow	25	29	199	65	18	4	340
	{−1·213}	{+3·558}	{−14·946}	{+10·261}	{+2·966}	{− ·626}	
Dull and Very Dull ...	3	1	73	8	5	4	94
	{−4·247}	{−6·034}	{+13·850}	{− 7·134}	{+ ·844}	{+2·721}	
Totals	68	66	555	142	39	12	882

square contingency C_2, but a knowledge of its value does not enable us to unravel the tangle of diverse causes at work. We give accordingly the table with the excess or defect of the observed cell contents from the contents if there were no association.

The value of $\phi'^2 = \cdot042{,}529$, while $\bar{\phi}^2 = \cdot026{,}078 \pm \cdot005343$, and ϕ^2 is therefore significant. The value of C_2' is accordingly ·2020; we cannot correct for class indices because we do not know what is the best order for the refraction categories. It would scarcely raise the resulting C_2 beyond ·25. The reader will find it difficult to interchange rows, or again columns, so as to give a more or less reasonable distribution of the + (or −) signs. As we have seen the Intelligent for the association of refraction class and intelligence need to be brought above the Very Able and Capable class. We can perhaps reach the best approach to diagonal clustering thus:

	Hypermetropia	Emmetropia	Hypermetropic Astigmatism	Myopia	Myopic Astigmatism	Mixed Astigmatism
Intelligent	+	+	−	−	−	−
Very Able and Capable	−	−	+	+	+	−
Slow	−	−	+	+	+	−
Dull and Very Dull ...	−	+	−	−	+	+

The weak point here still lies in the Very Able and Capable having a defect of normal eyes instead of an excess, and the Dull and Very Dull an excess of normal eyes instead of a defect. Contingency suggests that beyond the higher grades of intelligence being more myopic than the merely Intelligent, there is some other factor as yet unrecognised at work.

(vi) *Refraction Class and Place in Class.* We will now free ourselves from any influence of the teacher's appreciation of intelligence, and consider how refraction affects the boy's success as measured by place in class. Our data permit us to deal with 700 cases, given in Table CCXLVI.

Table CCXLVI. *Refraction Class and Place in Class (Boys).*

Refraction Class	Place in Class 1–2	3–4	5–6	7–8	9–10	11–12	13–14	15–16	17–18	19–20	21–22	23–24	25–26	27–28	29–30	31–32	33–34	35–36	37–38	39–40	41–42	43–44	45–46	47–48	49–50	Totals
Hypermetropia	1	4	3	—	4	—	7	—	4	3	3	6	1	2	1	—	—	—	2	2	2	4	2	1	3	55
Hypermetropic Astigmatism	2	1	—	2	1	7	1	4	2	4	3	7	—	2	—	4	3	4	—	1	2	—	—	1	—	51
Emmetropia	18	17	15	23	26	9	34	19	21	16	15	23	18	9	12	28	25	24	20	12	14	17	12	8	9	444
Myopia	5	—	3	8	5	14	7	2	6	9	4	2	9	8	4	6	4	—	5	—	3	5	—	—	2	111
Myopic Astigmatism	—	2	1	1	—	—	1	1	1	4	—	—	—	1	1	1	2	—	3	1	4	2	2	2	—	30
Mixed Astigmatism	—	—	—	—	—	2	—	—	—	—	1	—	—	—	2	1	—	—	—	2	1	—	—	—	—	9
Totals	26	24	22	34	36	32	50	26	34	36	26	38	28	22	20	40	34	28	30	18	26	28	16	12	14	700

The following are the mean places in class of those with

Hypermetropia	23·7545 ±1·208
Hypermetropic Astigmatism	22·0098 ±1·254
Emmetropia	23·7297 ± ·425
Myopia	21·1757 ± ·850
Myopic Astigmatism	29·7000 ±1·635
Mixed Astigmatism	28·3889 ±2·985
General Population	23·5171 ± ·338

It may be doubted whether there are any really significant differences between the means for the first three classes, but as in the matter of Intelligence, the myopic and mixed astigmatics had fewer per cent. in the intelligent classes, so in success in its application, they have the worst places in class, while with slightly more significance the myopes have the best.

If we consider the percentages in each refraction class of boys in the first twelve and last twelve places we have:

	Percentage in first 12 places	Percentage in last 12 places
Myopia	31·5	9·0
Hypermetropic Astigmatism ...	25·5	7·8
Emmetropia	22·3	16·2
Hypermetropia	21·8	25·5
Myopic and Mixed Astigmatism	15·4	35·9
General Population	24·9	16·3

It is clear from these results that while myopic astigmatism and mixed astigmatism are associated with lesser intelligence and more dulness, this is not the case with simple myopia, which has the greatest number of high places and nearly the smallest number of low places. It does not accordingly seem reasonable to assert, as some have done, that short sight is one of the chief sources of apparent stupidity and failure in school life.

If we contrast the myopes with all the other groups and form a fourfold table thus:

	Hypermetropia, Hypermetropic Astigmatism, Emmetropia	Myopic Astigmatism, Mixed Astigmatism, Myopia	Totals
High in Class, i.e. 1 to 22	269	77	346
Low in Class, i.e. 23 to 50	281	73	354
Totals	550	150	700

we find $$r_t = - \cdot 0349 \pm \cdot 0449,$$

or there is no significant relation between refraction class and success in school. But this results solely from our watering down simple myopia with its astigmatic varieties. There seems no reasonable division of the refraction classes, however, which will give any other fourfold table of value*. We therefore proceed to determine $\eta_{P.R}$ from the mean places in class of the various refraction groups. We find:

$$\eta'^2_{P.R} = \cdot 017{,}047, \text{ while } \bar{\eta}^2_{P.R} = \cdot 007{,}143 \pm \cdot 003{,}035.$$

We may consider $\eta'^2_{P.R}$ significant with regard to $\bar{\eta}^2_{P.R}$ and accordingly have

$$\eta'_{P.R} = \cdot 1306.$$

Thus we find much the same order of small relationship as we found in the case of Intelligence and Refraction Class. It is the myopic astigmatics rather than the simple myopes who are the trouble as far as intelligence is concerned.

(vii) *General Refraction and Intelligence.* While the grouping of refraction into classes is no doubt of value on the practical side, it is not very satisfactory from the statistical side, where we naturally prefer a quantitative measurement of refraction. Our data are given in Table CCXLVII and in Table CCXLVIII we exhibit them in an abbreviated form.

$$\eta'^2_{I.R} = \cdot 010{,}469, \quad \bar{\eta}^2_{I.R} = \cdot 006{,}803 \pm \cdot 002{,}639.$$

The difference of η'^2 and $\bar{\eta}^2$ is less than 1·4 times the probable error and we cannot assert any significant association between general refraction and intelligence.

* Even if it were reasonable to put Myopia in with Hypermetropia and Emmetropia, the Myopic and Mixed Astigmatism classes have too few individuals to give any reliable result.

Table CCXLVII. *Intelligence and General Refraction.*

Dioptres (Central Values[1])

	+6·75	+6·00	+5·25	+4·50	+3·75	+3·00	+2·25	+1·50	+0·75	+0·00	−0·75	−1·50	−2·25	−3·00	−3·75	−4·50	−5·25	−6·00	−6·75	..	−12·75	..	−15·75	Totals
Very Able	—	—	—	—	—	—	2	1	4	12	1	2	—	—	1	—	1	—	—	..	—	..	—	24
Capable	—	2	—	1	2	2	3	1	13·5	30·5	10	4	2	2	1	—	—	—	—	..	—	..	—	74
Intelligent	—	1	—	1	6·5	5·5	12·5	12	71	182·5	24·5	10·5	15	1	4	—	2	—	1	..	—	..	—	350
Slow	1	1	4	1	8	3	13	9	77·5	145·5	40·5	15·5	8	4	2	—	2	—	3	..	1	..	1	340
Dull	—	—	—	—	—	—	—	—	16	56	6	0·5	0·5	—	—	—	2	1	—	..	—	..	—	82
Very Dull	—	—	—	—	—	—	—	1	3	6	—	2	—	—	—	—	—	—	—	..	—	..	—	12
Totals	1	4	4	3	16·5	10·5	30·5	24	185	432·5	82	34·5	25·5	7	8	—	7	1	4	..	1	..	1	882

[1] Readings to 0·25 dioptre. Each reading contains three groups. Thus 3·0 contains 2·75, 3·00 and 3·25 or the range is from 2·625 to 3·375.

Table CCXLVIII. *Intelligence and General Refraction (abbreviated).*

Dioptres (Central Values and Ranges)

Range Central Value	Above 2·625 +4·07	2·625 to 1·125 +1·92	1·125 to ·375 +0·75	+·375 to −·375 0·00	−·375 to −1·125 −0·75	−1·125 to −2·625 −1·82	Below −2·625 −5·15	Totals —
Very Able and Capable...	7	7	17·5	42·5	11	8	5	98
Intelligent	14	24·5	71	182·5	24·5	25·5	8	350
Slow, Dull, and Very Dull	18	23	96·5	207·5	46·5	26·5	16	434
Totals	39	54·5	185	432·5	82	60	29	882

If we make a fourfold table with one dichotomic line at + ·375 dioptre and the other at the boundary of Intelligent and Slow we obtain the fourfold table:

	Above +·375 D.	Below +·375 D.	Totals
Intelligent and Above	141	307	448
Slow and Below ...	137·5	296·5	434
Totals	278·5	603·5	882

and this leads to $r_t = - \cdot0049 \pm \cdot0372.$

This is again an insignificant value, having regard to the probable error. Thus our conclusion from $\eta_{I.R}$ is confirmed. We are unable to assert any significant relation between intelligence and simple refraction.

(viii) *General Refraction and Place in Class.* As more weight is usually attributed to a table of quantitative measurements for both variables we have correlated General Refraction and Place in Class in Table CCXLIX. The following are the mean places in class at the corresponding central refraction values in dioptres:

Refraction	Mean Place in Class	Refraction	Mean Place in Class
+5·39	28·0455 ±2·703	0·00	23·9425 ±0·490
+3·75	19·0200 ±2·537	−0·75	23·0224 ±1·095
+3·00	16·3421 ±2·911	−1·50	25·7041 ±1·741
+2·25	21·1170 ±1·850	−2·25	22·4730 ±2·085
+1·50	22·8684 ±2·057	−3·375	14·9000 ±2·835
+0·75	23·9522 ±0·715	−5·86	24·5919 ±2·703

	Mean Refraction	Mean Place in Class
General Population	+0·1484	23·5171 ±0·301

Table CCXLIX. *Place in Class and General Refraction.*

General Refraction, Central Values	Place in Class	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26	27-28	29-30	31-32	33-34	35-36	37-38	39-40	41-42	43-44	45-46	47-48	49-50	
	6·75	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
	6·00	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	3
	5·25	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	2	—	—	—	—	4
	4·50	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	3
	3·75	—	2	—	—	2	2	—	—	—	1·5	—	2	—	—	—	—	—	2	—	—	1	—	—	—	—	12·5
	3·00	—	1	—	2	—	2	—	1	—	1·5	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	9·5
	2·25	1	—	1	—	—	2	4	2	2	0·5	1	3	1	1	—	2	—	1	—	—	—	—	1	1	—	23·5
	1·50	—	—	1	—	1	2	3	—	3	—	1	1	—	2	—	—	—	—	1	3	—	—	—	1	—	19
	0·75	4	3	8	7	10	6	14	5	9	4·5	8	9	7	2	8·5	11	3	4	2	4	3	8	6	4	7	157
	0·00	13	17	8	17	19	5	21	14	15	13	12	19	12	9·5	7	21	22·5	20	19	11	11	14	5·5	4	5	334·5
	−0·75	4	—	4	1	3	6	5·5	—	3	6	2	—	6	3	2·5	2	5·5	—	4	—	4	2	1·5	2	—	67
	−1·50	2	—	—	1	1	3	0·5	1	—	3	—	2	1	0·5	—	2	1	—	3	—	0·5	2	1	—	2	26·5
	−2·25	—	—	—	1	—	2	1	2	2	1	2	—	1	2	—	2	—	—	1	—	1·5	—	—	—	—	18·5
	−3·00	—	—	—	2	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	1	—	—	—	—	5
	−3·75	1	—	—	3	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
	−4·50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	−5·25	1	—	—	—	—	1	—	—	—	2	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	6
	−6·00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
	−6·75	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	4
		26	24	22	34	36	32	50	26	34	36	26	38	28	22	20	40	34	28	30	18	26	28	16	12	14	700

These means are most erratic, but that is accounted for by the small numbers in all but the three central arrays (i.e. those for + ·75, ·00 and − ·75). In fact having regard to their probable errors (calculated on the basis of no association) it is clear that none of the individual differences is really significant.

This is at once confirmed by calculating the coefficient of correlation; we find:

$$r = - \cdot 0027 \pm \cdot 0255.$$

In case it might be supposed that the regression is non-linear, we calculated the correlation ratio and found:

$$\eta'^2_{P.R} = \cdot 016{,}047, \qquad \bar{\eta}^2_{P.R} = \cdot 015{,}714 \pm \cdot 003{,}992,$$

$\eta'_{P.R}$ is accordingly non-significant.

We must therefore conclude that General Refraction has no influence on Intelligence, nor on success in study as evidenced by Place in Class.

(ix) *Corneal Refraction and Intelligence.* It is worth while studying Corneal Refraction to see the extent to which it, as a factor of General Refraction, confirms the results found for the latter.

If $43 + C_1$ represents the dioptric power in the direction of the axis, and C_2 what must be added to this for the refraction in the meridian perpendicular to the axis, then

$$\frac{1}{\rho_1} = \frac{43 + C_1}{337} \text{ and } \frac{1}{\rho_2} = \frac{43 + C_1 + C_2}{337}$$

are the two curvatures of the cornea in these meridians respectively. If $C_2 = 0$, there is no corneal astigmatism. C_1 and C_2 may be either positive or negative.

We shall select the refraction in the horizontal meridian or, if the principal axes of the cornea are oblique, the refraction in the meridian nearer to the horizontal. We tabulate this omitting the reducing factor $\frac{1}{337}$.

For the purpose of calculating $\eta_{I.CR}$ an abbreviated table was made giving ten classes only and three categories of intelligence.

Table CCL. *Corneal Refraction and Intelligence (A, B and C).*

Corneal Refraction (Central Values)

Intelligence Categories	38·125	38·625	39·125	39·625	40·125	40·625	41·125	41·625	42·125	42·625	43·125	43·625	44·125	44·625	45·125	45·625	46·125	46·625	47·125	47·625	Totals
Very Able	—	—	—	—	—	2	—	—	1	2	4	3	3	2	5	2	1·5	0·5	—	—	26
Capable	—	—	—	1	3	3	4	8	12	12	8	11	9	13	—	5	4	—	1	—	94
Intelligent	—	—	—	1	6	10	19	23	29	36	42	52	54	43	24	18	13	6	—	2	378
Slow	1	—	3	3	8	5	21	15	38	32	45	52	53	30	26	18	15	5	2	—	372
Dull	—	—	—	1	3	1	4	2	9	10	13	9	15	4	8·5	7	11·5	2	—	—	100
Very Dull	—	—	—	—	—	—	2	—	—	—	4	2	1	2	1	—	1	1	—	—	14
Totals	1	—	3	6	20	21	50	48	89	92	116	129	135	94	64·5	50	46	14·5	3	2	984

Table CCLI. *Abbreviated Table of Corneal Refraction and Intelligence.*

Corneal Refraction (Central Values)

	Under 40·875	41·375	42·125	42·625	43·125	43·625	44·125	44·625	45·375	Over 45·875	Totals
Very Able and Capable...	9	12	13	14	12	14	12	15	12	7	120
Intelligent	17	42	29	36	42	52	54	43	42	21	378
Slow, Dull, and Very Dull	25	44	47	42	62	63	69	36	60·5	37·5	486
Totals	51	98	89	92	116	129	135	94	114·5	65·5	984

We find: $\eta'^2_{I.CR} = \cdot 013{,}141$, $\bar{\eta}^2_{I.CR} = \cdot 009{,}146 \pm \cdot 028{,}931$.

Having regard to the probable error we see that $\eta'^2_{I.CR}$ is not significantly different from $\bar{\eta}^2_{I.CR}$, or we cannot assert that any association exists between Intelligence and Corneal Refraction.

The following are the Mean Corneal Refractions for each Intelligence Class:

Very Able	44·0385 ±·2050
Capable	43·1729 ±·1078
Intelligent	43·4861 ±·0538
Slow	43·4207 ±·0542
Dull	43·7400 ±·1046
Very Dull	43·6607 ±·2794
General Population ...	43·4774 ±·0333

Standard Deviation of General Population = 1·5501 ± ·0236.

It would be rash to assert definite significance in any of the mean differences, and this confirms the insignificance of the correlation ratio of intelligence on corneal refraction.

(x) *Corneal Refraction and Place in Class.* We can confirm our result for Intelligence by the table for these characters which are both quantitative.

From this table we find:

Mean: Place in Class 23·3892, Mean: Corneal Refraction 43·4675,
Standard Deviation: „ „ 13·3371, Standard Deviation: „ „ 1·5657,

Correlation: $r = -\cdot 0045 \pm \cdot 0242$,

which is insignificant.

Thus Place in Class appears to be uninfluenced by Corneal Refraction.

We have already drawn attention to the fact that we had some doubts as to the ophthalmologist *C*'s use of the ophthalmometer, his personal equation relative to *A* and *B* being considerable. Accordingly we repeated our correlations between Intelligence and Place in Class with Corneal Refraction, using *A* and *B*'s observations only.

Table CCLII. *Corneal Refraction and Place in Class (A, B and C).*

Corneal Refraction

Place in Class	38·125	38·625	39·125	39·625	40·125	40·625	41·125	41·625	42·125	42·625	43·125	43·625	44·125	44·625	45·125	45·625	46·125	46·625	47·125	47·625	Totals
1–2	—	—	—	—	1	2	—	2	3	2	4	3	4	3	4	2	—	—	—	—	30
3–4	—	—	—	—	—	—	—	—	1	1	6	7	—	7	3	2	0·5	0·5	—	—	28
5–6	—	—	—	—	—	—	—	2	3	3	2	1	8	1	2	—	—	—	—	—	22
7–8	—	—	—	2	—	3	3	1	3	6	1	4	2	4	3	3	2	—	1	2	40
9–10	—	—	—	—	—	—	—	4	3	3	6	5	6	6	2	3	2	—	—	—	40
11–12	—	—	—	—	—	—	2	3	7	1	1	7	5	5	1	2	—	2	—	—	36
13–14	—	—	—	—	2	2	3	5	3	4	7	3	7	12	—	6	3	1	—	—	58
15–16	—	—	—	—	—	—	2	2	2	4	5	2	3	4	3	5	2	—	—	—	34
17–18	—	—	—	—	2	2	2	1	4	2	2	6	6	5	1	—	3	—	—	—	36
19–20	—	—	—	—	2	1	3	—	6	7	2	4	6	3	3	—	1	—	—	—	38
21–22	—	—	—	—	3	1	3	6	1	1	7	5	2	4	—	1	—	—	—	—	34
23–24	—	—	2	1	2	1	1	2	5	1	3	3	6	3	3	1	2	2	—	—	38
25–26	—	—	—	—	—	2	2	1	3	5	5	5	4	1	1	1	—	—	—	—	30
27–28	—	—	—	1	—	1	2	—	3	4	4	4	2	2	1	—	—	—	—	—	24
29–30	—	—	—	—	1	2	1	—	—	3	3	—	3	2	—	2	4	1	—	—	22
31–32	—	—	—	1	—	—	1	2	3	4	3	6	6	3	4	2	4	1	—	—	40
33–34	—	—	—	—	1	—	2	2	3	3	7	8	5	2	3	—	1	—	1	—	38
35–36	—	—	—	—	—	—	1	2	2	5	4	3	2	2	4	3	1	1	—	—	30
37–38	—	—	—	—	—	—	—	2	4	4	4	3	7	3	4	3	—	—	—	—	34
39–40	—	—	—	—	1	—	2	1	—	—	1	6	—	4	3	—	1	1	—	—	20
41–42	—	—	—	—	—	1	3	1	2	5	2	3	1	2	1·5	3	1·5	—	—	—	26
43–44	1	—	—	—	—	2	1	1	1	2	6	3	5	2	—	—	3	1	—	—	28
45–46	—	—	—	—	—	—	—	1	1	1	1	2	6	2	2	1	3	—	—	—	20
47–48	—	—	—	—	2	1	1	—	2	2	2	—	—	—	2	1	1	—	—	—	14
49–50	—	—	—	—	—	—	—	—	3	1	3	4	3	1	1	—	—	—	—	—	16
Totals	1	—	2	5	17	21	35	41	68	74	91	97	99	83	51·5	41	35	10·5	2	2	776

Table CCLIII. *Corneal Refraction and Intelligence (A and B only).*

Corneal Refraction (Central Values)

Intelligence Categories	38·125	38·625	39·125	39·625	40·125	40·625	41·125	41·625	42·125	42·625	43·125	43·625	44·125	44·625	45·125	45·625	46·125	46·625	47·125	47·625	Totals
Very Able	—	—	—	—	—	—	—	—	1	2	2	3	3	1	4	1	0·5	0·5	—	—	18
Capable	—	—	—	—	3	1	1	2	3	3	3	3	4	9	—	5	4	—	1	—	42
Intelligent	—	—	—	—	4	—	1	3	6	12	12	22	20	17	10	9	9	5	1	1	132
Slow	1	—	—	—	2	3	7	6	10	13	13	20	25	17	14	7	12	4	1	1	156
Dull	—	—	—	—	1	—	—	1	3	4	6	4	7	1	6	2	5	—	—	—	40
Very Dull	—	—	—	—	—	—	—	—	—	—	2	2	1	1	—	—	1	1	—	—	8
Totals	1	—	—	—	10	4	9	12	23	34	38	54	60	46	34	24	31·5	10·5	3	2	396

A triserial reduced table for this, namely:

	Under 42 D.[1]	42·375 D.	43·375 D.	44·375 D.	45·375 D.	Over 46	Totals
Very Able and Capable ...	7	9	11	17	10	6	60
Intelligent	8	18	34	37	19	16	132
Slow, Dull, and Very Dull	21	30	47	52	29	25	204
Totals	36	57	92	106	58	47	396

[1] Mean 40·875 D.

This gave for the correlation of Intelligence on Corneal Refraction $\eta'_{I.CR}$:

$\eta'^2_{I.CR} = \cdot 009{,}571$, $\bar{\eta}^2_{I.CR} = \cdot 012{,}626 \pm \cdot 005{,}128$, or there is no significant association.

If the means of corneal refraction for the separate categories be taken we find:

Very Able	...	...	...	44·111 ±·317
Capable	...	...	...	43·756 ±·208
Intelligent	...	...	...	44·045 ±·117
Slow	...	...	...	43·808 ±·108
Dull	...	...	...	43·950 ±·213
Very Dull	...	...	...	44·375 ±·476
General Mean	...	...	43·921 ±·068	Standard Deviation 1·9970

None of the means of the arrays differs significantly from that of the general population.

Corneal Refraction and Place in Class for A and B only. Turning now to Corneal Refraction and Place in Class for *A* and *B* only, we have the data given in Table CCLIV on p. 308.

From this table we deduce:

Mean: Place in Class 24·1071, Mean: Corneal Refraction 43·9204,
Standard Deviation: „ „ 14·4168, Standard Deviation: „ „ 1·5650,
Product Moment Correlation $-$ ·1331 $\pm$ ·0361.

Correlation Ratio of Place in Class on Corneal Refraction:

$$\eta'^2 = \cdot 055{,}628, \qquad \bar{\eta}^2 = \cdot 035{,}714 \pm \cdot 009{,}644.$$

The correlation coefficient is certainly significant and the correlation ratio ($\eta' = \cdot 2359$) is just possibly so. It would thus appear that, taken apart from *C*, the observations of *A* and *B* do show a sensible if small correlation between Corneal Refraction and Place in Class. Diagram 125 indicates that the regression line is probably skew and it was accordingly fitted with the cubic:

$$C.P. = 252{\cdot}9359 - 1{\cdot}5960\,(C.R.) - \cdot 2583\,(C.R.)^2 + \cdot 0040\,(C.R.)^3,$$

where $C.P.$ = class-place and $C.R.$ = corneal refraction in dioptres.

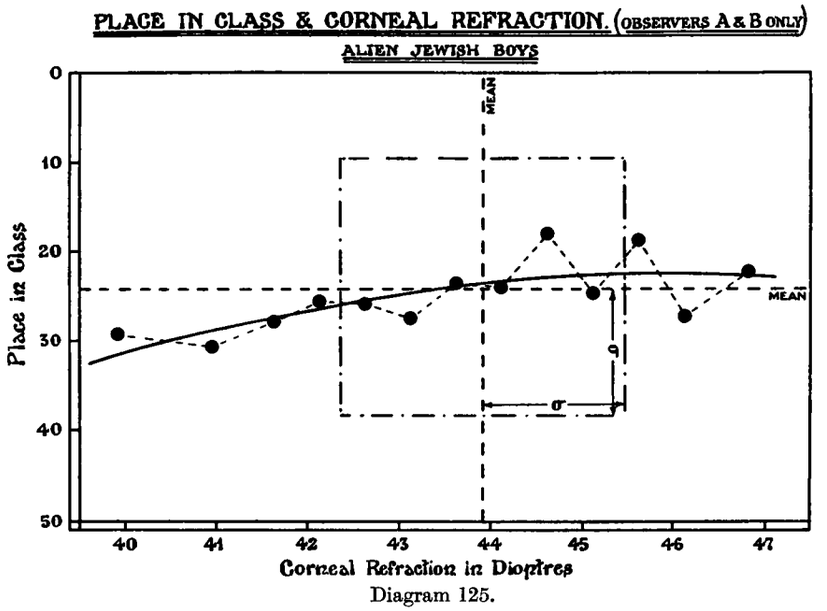

Diagram 125.

The curve indicates that high position in class is associated with increasing corneal refraction; the maximum place is reached, however, at the value of $C.R. = 45{\cdot}945$, where the class-place is 22·315, differing, however, only 1·792 or less than two places from the mean place 24·107.

It will thus be seen that a high corneal refraction connotes a small but sensible betterment in

position in class; a low corneal refraction indicates a more serious loss of place amounting to 31·816 – 24·107 or 7·709 places for a corneal refraction of 40 dioptres. We may ask why there is no sign of this in our data for Intelligence and Corneal Refraction. There are two points to be remembered here; First, Place in Class is not identical with Intelligence only substantially correlated; a trained teacher will recognise and record intelligence even when physical disadvantages do not permit of a high place in class. Secondly, although the extent of our data does not permit of our asserting that the correlation ratio of Intelligence on Corneal Refraction is significant, the mean values of intelligence for the several corneal refraction categories do show a variation of intelligence similar to that of place in class even if far less intense. Measured in mentaces we find:

	Intelligence from Mean
Under 40 (40·875 D.)	−28·478 mentaces
42·375 D.	− 3·216 „
43·375 D.	+ 1·331 „
44·375 D.	+ 6·280 „
45·375 D.	+ 3·831 „
46·364 D.	− 3·760 „

Although compared with a standard deviation of 100·806 mentaces these are small variations, they indicate for low corneal refraction a diminished intelligence, a small maximum about 45 D. followed by a drop between 46 D. and 47 D. Similar variations are all indicated, if more markedly, in the cubic of Diagram 125 for Place in Class.

We conclude, therefore, that a low corneal refraction and probably a high corneal refraction also do correspond to a small drop in intelligence, and that this drop rapidly diminishes, its effect being insensible at about 43·5 D. and then intelligence is gained up to about 44·5 D., when the maximum is reached. (This corresponds to about 2 class-places above the mean at 5·5 D. in our cubic of Diagram 125.) Greater corneal refraction connotes a slow fall of intelligence to the mean or below. We have here probably an illustration that great divergence from type in either direction is disadvantageous. In this low corneal refraction seems to be the more detrimental.

Table CCLIV. *Corneal Refraction and Place in Class (A and B only).*

Corneal Refraction (Central Values) \ Place in Class	1–2	3–4	5–6	7–8	9–10	11–12	13–14	15–16	17–18	19–20	21–22	23–24	25–26	27–28	29–30	31–32	33–34	35–36	37–38	39–40	41–42	43–44	45–46	47–48	49–50	Totals
38·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
38·625	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
39·125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
39·625	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
40·125	1	—	—	—	—	—	1	—	—	—	3	—	—	—	—	—	1	—	—	1	—	—	—	2	—	9
40·625	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	2	—	—	—	4
41·125	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	2	—	—	—	2	—	—	—	—	7
41·625	—	—	—	—	—	—	—	2	—	—	3	—	—	—	—	2	1	—	—	1	—	—	1	—	—	10
42·125	2	—	—	1	1	—	1	2	1	1	—	—	—	3	—	2	—	—	—	—	—	1	1	—	3	19
42·625	1	1	2	1	2	—	1	—	—	3	1	1	1	4	2	—	—	1	—	—	2	2	1	2	1	29
43·125	2	2	2	—	1	—	2	—	1	—	2	2	3	1	—	1	2	1	—	—	2	3	1	2	3	33
43·625	3	3	1	2	4	2	2	1	5	—	1	2	—	—	—	3	1	3	1	2	1	3	2	—	3	45
44·125	2	—	6	1	2	3	2	2	2	2	—	3	1	—	1	6	4	1	2	—	1	3	2	—	2	48
44·625	3	2	1	3	4	4	8	1	1	2	2	1	1	—	1	3	1	—	—	—	2	1	2	—	—	43
45·125	2	2	2	2	—	1	—	1	1	—	—	2	1	—	—	4	2	—	2	2	—	—	2	2	—	28
45·625	—	1	—	3	2	—	5	1	—	—	—	1	1	—	—	2	—	—	3	—	—	—	—	—	—	19
46·125	—	0·5	—	2	—	—	2	2	3	—	—	2	—	—	3	4	1	1	—	1	—	3	2	—	—	26·5
46·625	—	0·5	—	—	—	2	1	—	—	—	—	2	—	—	1	1	—	1	—	1	—	1	—	—	—	10·5
47·125	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	2
47·625	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Totals	16	12	14	18	16	12	26	12	14	8	16	16	8	8	8	28	16	8	8	8	10	20	14	8	12	336

(xi) *Intelligence and General Astigmatism.* The following table gives our data for the association of these traits.

Table CCLV. *Intelligence and General Astigmatism.*

Intelligence Category	General Astigmatism in Dioptres											
	+3·00	+2·25	+1·50	+0·75	0·00	−0·75	−1·50	−2·25	−3·00	−3·75	−4·50	−5·25	Totals
Very Able	—	—	—	1	17	3	3	—	—	—	—	—	24
Capable	—	—	—	5	50	10	2	2	2	1	1	1	74
Intelligent	0·5	1·5	—	17·5	269	34·5	9	13·5	2·5	2	—	—	350
Slow	—	—	4	28·5	241	39·5	8	12	1	4	2	—	340
Dull	—	—	—	1·5	65	11·5	—	3	1	—	—	—	82
Very Dull	—	—	—	—	10	1	1	—	—	—	—	—	12
Totals	0·5	1·5	4	53·5	652	99·5	23	30·5	6·5	7	3	1	882

The condensed table used for computing the correlation ratio ($\eta_{I.A}$) of intelligence on general astigmatism was:

	+0·857	0·00	−0·75	−1·50	−2·25	−3·686	Totals
Very Able and Capable ...	6	67	13	5	2	5	98
Intelligent	19·5	269	34·5	9	13·5	4·5	350
Slow, Dull, and Very Dull	34	316	52	9	15	8	434
Totals	59·5	652	99·5	23	30·5	17·5	882

the astigmatism being in dioptres at central values. We found:

$$\eta'^2_{I.A} = \cdot 007{,}272, \qquad \bar{\eta}^2_{I.A} = \cdot 005{,}669 \pm \cdot 002{,}411,$$

$\eta'^2_{I.A}$ is therefore non-significant, having regard to $\bar{\eta}^2_{I.A}$, and we cannot assert any definite association.

The means of the various arrays are as follows:

	Mean below or above General Mean
At +0·857 D.	−18·03 ± 7·11 mentaces
„ 0·00 D.	+ 1·32 ± 2·15 „
„ −0·75 D.	− 6·93 ± 5·50 „
„ −1·50 D.	+24·49 ±11·43 „
„ −2·25 D.	− 0·27 ± 9·93 „
„ −3·686 D.	+14·36 ±13·11 „
General Population	0·00 ± 1·85 „

Standard Deviation of Population: 81·2678 mentaces.

None of these can be asserted to be definitely significant, and the series as a whole presents no continuity, being just the sort of deviations we might anticipate from random sampling.

(xii) *Place in Class and General Astigmatism.* Table CCLVI (p. 310) gives our data for *A*, *B* and *C*. The constants of this table are as follows:

Mean: Place in Class 23·5171 General Astigmatism − ·1993 D.
Standard Deviation: „ „ 13·2906 „ „ ·7289 D.

Correlation Coefficient from Product Moment: $r = \cdot 0079 \pm \cdot 0255$.

Correlation Ratio of Place in Class on General Astigmatism:

$$\eta'^2_{P.A} = \cdot 007{,}030, \qquad \bar{\eta}^2_{P.A} = \cdot 008{,}571 \pm \cdot 003{,}323.$$

Table CCLVI. *Place in Class and General Astigmatism.*

General Astigmatism (Dioptres)	Place in Class 1–2	3–4	5–6	7–8	9–10	11–12	13–14	15–16	17–18	19–20	21–22	23–24	25–26	27–28	29–30	31–32	33–34	35–36	37–38	39–40	41–42	43–44	45–46	47–48	49–50	Totals
+3·00	—	—	—	—	—	—	—	—	—	0·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·5
+2·25	—	—	—	—	—	—	—	1	—	0·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·5
+1·50	—	—	—	—	—	—	—	—	—	—	—	—	—	0·5	0·5	2	1	—	—	—	—	—	—	—	—	4
+0·75	2	1	2	1	5	1	3·5	—	5	2	2	5	—	—	—	1	3·5	—	4	—	1·5	1	0·5	3	2	46
0·00	17	19	18	29	26	20	42	17	24	22	20	27	24	18	14	28	23	20	22	13	19	21	13	8	12	516
−0·75	3	2	2	3	4	3	4·5	5	5	4	2	1	4	2	4	7	4·5	6	3	2	1·5	5	2·5	—	—	80
−1·50	4	2	—	—	—	—	—	1	—	1	2	1	—	1·5	1·5	—	—	—	—	1	1	—	—	—	—	16
−2·25	—	—	—	—	—	6	—	2	—	1·5	—	3	—	—	—	2	—	1	1	1	3	1	—	1	—	22·5
−3·00	—	—	—	1	—	2	—	—	—	0·5	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	5·5
−3·75	—	—	—	—	1	—	—	—	—	2	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	4
−4·50	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	3
−5·25	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Totals	26	24	22	34	36	32	50	26	34	36	26	38	28	22	20	40	34	28	30	18	26	28	16	12	14	700

Accordingly we see that the association upon our data is of no significance. This is well illustrated in the following table of means of the arrays and graphically in Diagram 126.

General Astigmatism	Mean Place in Class
At +1·69 D.	26·67 ±3·66
„ +0·75 D.	23·59 ±1·32
„ 0·00 D.	23·48 ±0·39
„ −0·75 D.	24·13 ±1·00
„ −1·50 D.	17·56 ±2·24
„ −2·25 D.	26·26 ±1·89
„ −3·72 D.	21·72 ±2·44
General Population	23·52 ±0·34

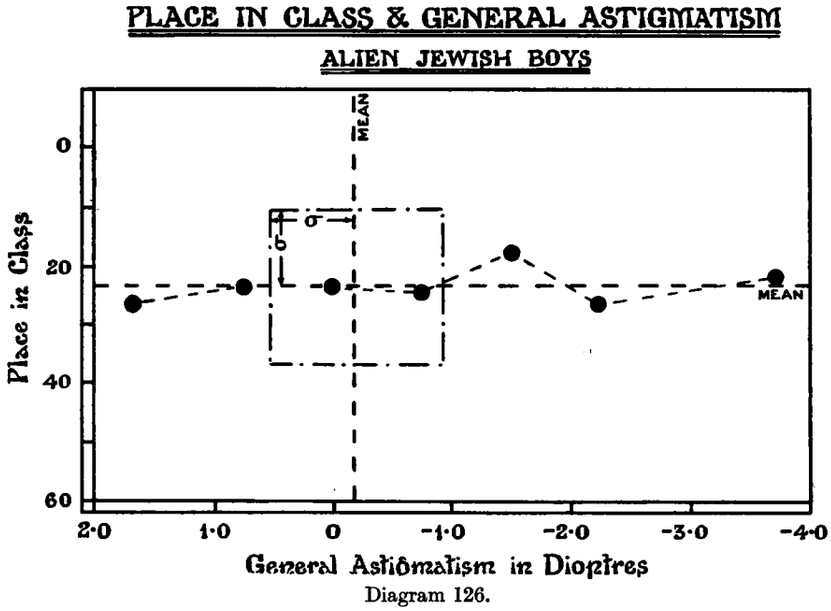

Diagram 126.

The array mean at −1·50 D. is the only one which differs significantly from the mean of the general population, but it depends upon only 16 individuals, six of whom were in the first four class-places, i.e. it suffices to indicate that a moderate amount of astigmatism does not hinder a boy taking a high place in class. We are unable to assert that astigmatism sensibly influences intelligence or affects a boy's place in class.

(xiii) *Corneal Astigmatism and Intelligence.* Tables CCLVII and CCLVIII give our data for observers *A*, *B*, *C* and for *A*, *B* alone, respectively.

Tables CCLVII and CCLVIII. *Corneal Astigmatism and Intelligence.*

Corneal Astigmatism in Dioptres	Observers *A*, *B* and *C*							Observers *A* and *B*						
	Intelligence						Totals	Intelligence						Totals
	Very Able	Capable	Intelligent	Slow	Dull	Very Dull		Very Able	Capable	Intelligent	Slow	Dull	Very Dull	
−2·25	—	—	1	—	—	—	1	—	—	—	—	—	—	—
−1·50	—	—	3	4	—	—	7	—	—	1	4	—	—	5
−0·75	2	—	10	3	3·5	—	18·5	2	—	8	3	3	—	16
0·00	12	42	170	154	41	6	425	7	20	36	40	3	1	107
+0·75	9	32	138	155	41·5	3	378·5	8	14	67	79	26	2	196
+1·50	1	6	34	27	2	2	72	—	1	15	11	1	2	30
+2·25	1	8	12	16	9	2	48	—	2	2	12	5	2	23
+3·00	1	3	8	6	—	—	18	1	3	3	1	—	—	8
+3·75	—	—	1	5	2	—	8	—	—	—	4	2	—	6
+4·50	—	—	1	2	—	—	3	—	—	—	2	—	—	2
+5·25	—	3	—	—	—	1	4	—	2	—	—	—	1	3
+6·00	—	—	—	—	1	—	1	—	—	—	—	—	—	—
Totals	26	94	378	372	100	14	984	18	42	132	156	40	8	396

The constants of these distributions are as follows:

		A, *B*, *C*	*A*, *B* only
Mean:	Corneal Astigmatism	+ ·6075 D. ± ·0204 D.	+ ·7462 D. ± ·0321 D.
Standard Deviation:	„ „	·8562 D. ± ·0144 D.	·9467 D. ± ·0227 D.

These values for the means and standard deviations are adequate to show that either *C*'s personal equation differed widely from *A* and *B*'s, or that a different group of boys was submitted to him. As he took the boys whose schedules had been filled up for "Intelligence," but who had not yet had their sight tested, the second alternative seems unlikely.

In the case of the *A*, *B*, *C* data we find

$$r = -\cdot0496 \pm \cdot0214, \quad \eta'^2_{I.CA} = \cdot009{,}203, \quad \bar{\eta}^2_{I.CA} = \cdot005{,}081 \pm \cdot002{,}161,$$

which can hardly be considered of any value were they judged to be significant.

The mean of the whole population is + ·4150 mentaces on the "Intelligent" side of the boundary between "Intelligent" and "Slow," while the Standard Deviation is 84·71 mentaces. Looked at from the standpoint of mean of arrays we have:

Array at	Deviation from Mean towards Higher Capacity
−1·00 D.	+15·07 ± 11·10 mentaces
0·00 D.	+ 5·19 ± 2·77 „
+0·75 D.	− 6·23 ± 2·93 „
+1·50 D.	+11·47 ± 6·73 „
+2·25 D.	−22·06 ± 8·25 „
+3·66 D.	− 0·42 ± 9·80 „
General Population	0·00 ± 1·82 „

None of these values appears significant, having regard to their probable errors, and we cannot assert on these observations that Corneal Astigmatism really influences the intelligence.

If we turn to the observations of *A* and *B only*, we have the following results for the means of arrays both ways:

Mean Corneal Astigmatism for given Intelligence Grade	
Very Able	+ ·4167 D. ±·1505 D.
Capable	+ ·8571 D. ±·0985 D.
Intelligent	+ ·5966 D. ±·0556 D.
Slow	+ ·7788 D. ±·0502 D.
Dull and Very Dull	+1·0781 D. ±·0922 D.
General Population	+ ·7462 D. ±·0321 D.

Mean Deviation from Mean Intelligence for given Corneal Astigmatism	
−0·93 D.	+ 8·20 ±14·84 mentaces
0·00 D.	+29·01 ± 6·57 ,,
+0·75 D.	− 6·61 ± 4·86 ,,
+1·83 D.	−20·74 ± 9·34 ,,
+3·75 D.	−12·13 ±15·60 ,,
General Population	·00 ± 3·42 ,,

Only two of the former results may be considered significant, that which makes the "Very Able" have the least corneal astigmatism and the "Dull" and "Very Dull" group the most, the other categories give erratic and non-significant variations. Of the latter results only one is significant, namely: the category of no astigmatism has the highest intelligence. It does appear again as if *C*'s observations had in some way obscured the results, and it seems as if increasing corneal astigmatism reduced the intelligence below its mean value—all the signs for the intelligence means when corneal astigmatism is with the rule are *negative*, although the individual values are erratic.

To obtain some comparative measure of the influence we proceeded to find $\eta'_{I.A}$ from the above five arrays, and tetrachoric r_t from the fourfold table:

Intelligence

Corneal Astigmatism	Very Able, Capable, and Intelligent	Slow, Dull, and Very Dull	Totals
None, or Against the Rule	74	54	128
With the Rule	118	150	268
Totals	192	204	396

We obtained: $\eta'^2_{I.A} = ·030{,}031$, $\bar{\eta}^2_{I.A} = ·010{,}101 \pm ·004{,}793$,

$r_t = ·2090 \pm ·0536$.

Both η'^2 and r_t are significant, and $\eta' = ·1733$; the class-index correlation is ·9967 so that the correlation ratio of ability on corneal astigmatism is $\eta = ·1739$*. We may take it therefore as fairly certain that, with careful observations, we shall find a small but significant correlation between corneal astigmatism and intelligence, the higher the astigmatism with the rule the less intelligent the boy. The general trend is indicated in Diagram 127. It will be seen that we can hardly, on our data, take anything better than linear regression.

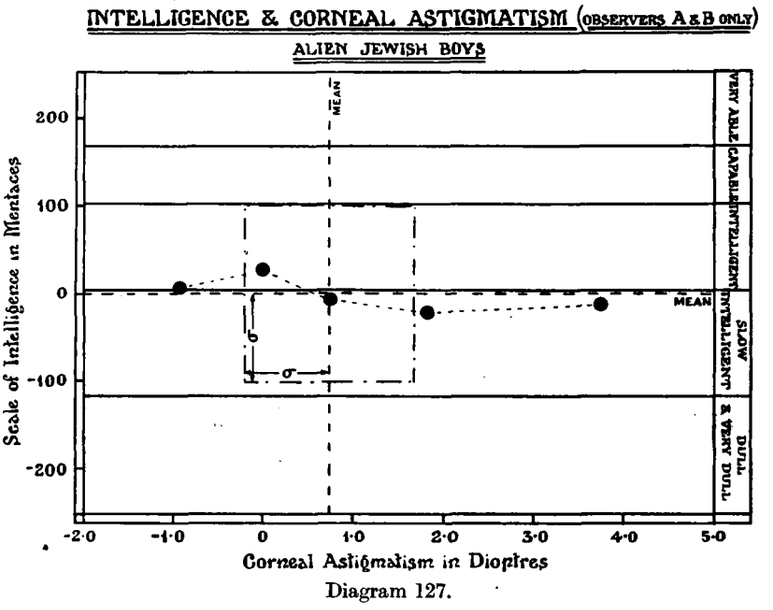

Diagram 127.

It may appear somewhat strange that while we have found small but definite traces of a relation between

* The reader must bear in mind that throughout this discussion it must not be assumed as in the case of product moment methods that corrected η is $> r$; the methods used give only approximate values, which serve as mutual checks.

Corneal Astigmatism and Intelligence (when we confine our data to those due to *A* and *B*) we have been unable to detect any such association either between Intelligence or Place in Class and General Astigmatism. While fully aware of the observational difficulties involved, especially when they are of the mass kind attempted in the present records, we would point out that we know of no similar observations in which an attempt has been made to ascertain the association of Intelligence with ocular characters. There are no control statistical series, we have only ophthalmologist's impressions, often contradictory and based on vague and occasionally slender experience. Until statistical investigations have been made, it is not possible to ascertain to what extent any ocular traits are associated with intelligence. It is conceivable, if it does not seem *a priori* probable, that a part of astigmatism—the corneal—may be more highly correlated (if it be right with such intensities to use the term "high" at all) than the whole. This problem will only be solved when more elaborate and more extensive observations are available.

(xiv) *Corneal Astigmatism and Place in Class.* We next discuss the relation of Place in Class to that part of astigmatism due to the difference in the curvatures of the cornea.

Table CCLIX. *Corneal Astigmatism and Place in Class (A, B and C).*

Corneal Astigmatism in Dioptres	Place in Class (reduced to standard class of 50)																								
	1–2	3–4	5–6	7–8	9–10	11–12	13–14	15–16	17–18	19–20	21–22	23–24	25–26	27–28	29–30	31–32	33–34	35–36	37–38	39–40	41–42	43–44	45–46	47–48	49–50	Totals
−2·25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
−1·50	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	4	—	—	—	1	—	—	—	—	—	7
−0·75	1	1	1	—	2	1	—	—	1	—	1	—	—	—	—	1	2	—	1	—	—	—	—	—	1	13
0·00	14	13	8	10	18	9	29	14	16	15	16	26	15	15	9	9	11	14	25	12	10	8	5	7	3	331
+0·75	11	6	11	25	13	17	22	14	15	11	12	6	13	5	11	22	17	11	6	2	11	16	12	6	9	304
+1·50	1	7	1	1	5	3	4	2	—	5	1	2	2	3	2	2	3	2	—	—	1	4	1	—	1	53
+2·25	1	—	1	2	1	1	3	1	2	3	3	1	—	1	—	—	1	1	2	2	3	—	1	1	2	33
+3·00	2	1	—	2	—	3	—	2	—	2	—	2	—	—	—	2	—	1	—	—	1	—	—	—	—	18
+3·75	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	1	1	—	2	—	—	—	—	—	6
+4·50	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	2
+5·25	—	—	—	—	1	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	4
Totals	30	28	22	40	40	36	58	34	34	38	34	38	30	24	22	40	36	30	34	20	26	28	20	14	16	772

Here we shall treat separately the combined observations of *A*, *B* and *C*, and those for *A* and *B* only, as on the previous occasions where we have dealt with the ophthalmometer records. We find:

Mean: Place in Class 23·2668 Corneal Astigmatism ·6033 D.
Standard Deviation: „ „ 13·3583 „ „ ·8557 D.
Product Moment Correlation − ·0220 ± ·0242.

There is accordingly no significant coefficient of correlation between corneal astigmatism and place in class. If we take the means corresponding to rising values of the astigmatism we have:

Corneal Astigmatism	Mean Place in Class	No. of Cases
−1·07 D.	24·548 ±1·966	21
0·00 D.	23·228 ± ·495	331
+0·75 D.	23·598 ± ·517	304
+1·50 D.	20·934 ±1·238	53
+2·51 D.	22·754 ±1·262	51
+4·375 D.	26·166 ±2·601	12
General Population	23·267 ±·324	772

Not one of these means is really significantly different from that of the general population, having regard to the probable errors. There does appear to be some slight tendency for corneal astigmatism much with or much against the rule to have a lower average place in class, but our numbers in the extreme classes are too small for us to be sure of this.

We will now throw out *C*'s observations although this much reduces our available material—and accordingly increases our probable errors—and see if we get a more uniform trend. The distribution is given in Table CCLX and the constants are:

Mean: Place in Class 24·1071 Corneal Astigmatism ·7232 D.
Standard Deviation: „ „ 14·4168 „ „ ·9434 D.
Product Moment Correlation Coefficient + ·0974 ± ·0365.

Correlation ratio: Corneal Astigmatism on Age:

$$\eta'^2_{P.CA} = \cdot 062{,}583, \qquad \bar{\eta}^2_{P.CA} = \cdot 020{,}833 \pm \cdot 007{,}383.$$

Table CCLX. *Corneal Astigmatism and Place in Class (A and B only).*

Corneal Astigmatism in Dioptres \ Place in Class	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26	27-28	29-30	31-32	33-34	35-36	37-38	39-40	41-42	43-44	45-46	47-48	49-50	Totals
−1·50	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	4	—	—	—	—	—	—	—	—	—	5
−0·75	1	1	1	—	2	1	1	—	1	—	1	—	—	—	—	1	2	—	1	—	—	—	—	—	1	14
0·00	7	5	4	3	3	3	9	—	5	3	5	9	2	5	1	5	4	2	3	4	1	3	2	3	1	92
+0·75	6	3	9	13	9	8	11	8	7	1	7	6	5	1	5	17	7	3	2	—	6	14	9	4	7	168
+1·50	—	2	—	—	2	—	3	1	—	2	—	—	1	1	2	1	—	1	—	1	—	3	1	—	1	22
+2·25	—	—	—	—	—	—	2	1	1	—	2	1	—	1	—	—	1	—	2	1	3	—	1	1	2	19
+3·00	2	1	—	2	—	—	—	2	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	8
+3·75	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	2	—	—	—	—	—	4
+4·50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
+5·25	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	3
Totals	16	12	14	18	16	12	26	12	14	8	16	16	8	8	8	28	16	8	8	8	10	20	14	8	12	336

It is clear that the correlation coefficient is now of opposite sign, i.e. positive corneal astigmatism is associated with low place in class; it may be just significant. Further, η'^2 is significant, having regard to $\bar{\eta}^2$, and we have an uncorrected correlation ratio $\eta' = \cdot 2502$. The means of the arrays give us a clue to the nature of the relationship:

Corneal Astigmatism	Mean Place in Class	No. of Cases
−0·947 D.	23·974 ±2·231	19
0·00 D.	22·043 ±1·014	92
+0·75 D.	23·452 ± ·750	168
+1·50 D.	25·682 ±2·073	22
+2·472 D.	26·167 ±1·871	27
+4·406 D.	32·250 ±3·348	8
General Population	24·107 ± ·531	336

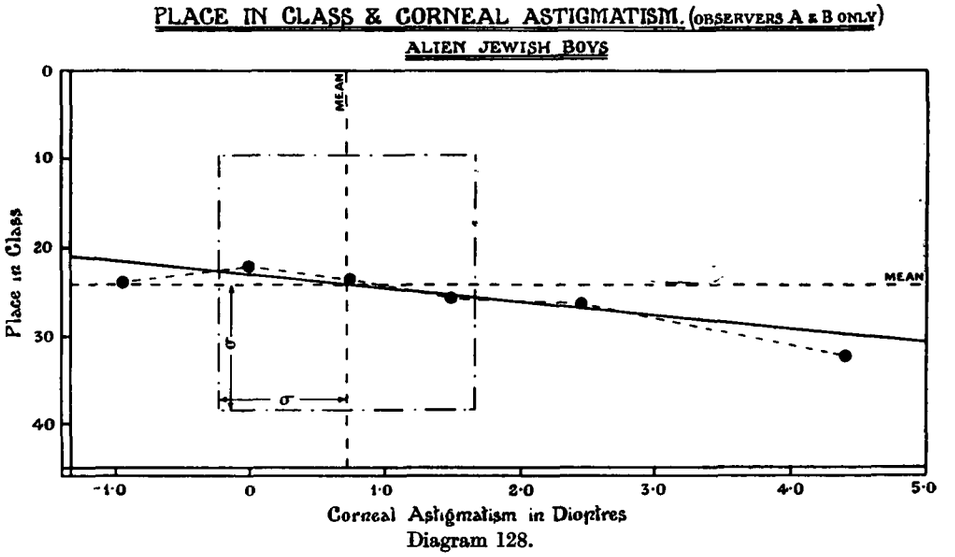

Diagram 128.

These results, although based on small numbers, are much smoother, we now see that there is little real influence of corneal astigmatism against the rule, but that with the rule the place in class falls steadily until the average place may be eight below the mean. We say "may be" because our data for more than + 2·25 D. are very slender and the class-place of over 32 at 4·406 D. is based only on eight cases! The loss of place owing to this form of astigmatism is not really very marked, but it appears significant and must be borne in mind. It confirms the conclusion for Intelligence and Corneal Astigmatism. Diagram 128 shows the results graphically.

(xv) *Intelligence and Appearance of the Fundus.* As a last ocular character we may take the appearance of the fundus which was distributed into four categories, Light, Moderately Light, Moderately Dark, Dark. We then have the following table:

Table CCLXI. *Intelligence and Appearance of Fundus.*

	Intelligence Grade						
	Very Able	Capable	Intelligent	Slow	Dull	Very Dull	Totals
Light	0·5	—	4	6	3	—	13·5
Moderately Light	5·5	25	107·5	91	27	3	259
Moderately Dark	6	20	67·5	82	16	2	193·5
Dark	2	2	11	8	3	2	28
Totals	14	47	190	187	49	7	494

Adopting in the first place a fourfold division with the dichotomic lines between Intelligent and Slow, and Light and Dark Fundus, we reach the tetrachoric table:

	Very Able, Capable, and Intelligent	Slow, Dull, Very Dull	Totals
Light	142·5	130	272·5
Dark	108·5	113	221·5
Totals	251	243	494

leading to a coefficient of correlation:

$$r_t = \cdot 0518 \pm \cdot 0477,$$

a value which is insignificant having regard to its probable error.

It might, however, be argued that extremes are both likely to affect intelligence adversely, and to ascertain whether this is so we found the mean intelligence of each fundus category measured from the mean of the intelligence of the whole population. The "Intelligence" range was taken as 100 mentaces, and we used the intelligence distribution given for 984 eyes (see p. 311). There resulted:

	Mean Intelligence of Category	
Light Fundus	−29·6273 ±15·559	mentaces
Moderately Light Fundus	+ 1·8873 ± 3·5502	„
Moderately Dark Fundus	+ 1·6086 ± 4·1084	„
Dark Fundus	− 2·6912 ±10·7980	„

Here, as we anticipated, it might possibly be that boys both with extremely light and dark fundi have less than the mean intelligence of the population, but having regard to their probable errors none of these group-means is really differentiated significantly. We cannot assert on the basis of our data that the colour of the fundus affects intelligence. But the suggestion is a very interesting one and wants investigating on a much larger scale. Unfortunately the Galton Laboratory has no funds for carrying out investigations in the field, such as an adequate study of school children's eyesight involves.

(xvi) *Intelligence and Rickets in Girls.* While we were dealing with the influence of various eye defects on intelligence our attention was drawn to the fact that in the latter part of the medical examination "Previous Rickets as indicated by the thoracic wall" had been recorded. The classes were: (1) no evidence, (2) suspicion from depression of sternum or other signs, (3) definite evidence in Harrison's groove, sternal depression, etc. The data taken were only adequate in the case of girls, where we had 401 examined for rickets. Although this is hardly the proper section to consider the matter, we include it here in order not to waste careful observations, which may be of some interest. Table CCLXII gives the record.

Table CCLXII. *Intelligence and Rickets (Girls).*

Intelligence Categories	Condition as to Rickets			Totals
	1	2	3	
Very Able	3	1	—	4
Capable	14	3	3	20
Intelligent	79	23	6	108
Slow	93	36	9	138
Dull	46	21	9	76
Very Dull[1]	37	14	4	55
Totals	272	98	31	401

Tetrachoric Table

Intelligence Categories	Rickets		Totals
	1	2+3	
Very Able, Capable, Intelligent ...	96	36	132
Slow, Dull, Very Dull, M. Defective	176	93	269
Totals	272	129	401

[1] Includes under (1) three and under (2) one mentally defective girl.

Worked from the tetrachoric table the value of the correlation coefficient is

$$r_t = \cdot 1257 \pm \cdot 0564,$$

less intelligence being associated with greater evidence for rickets. The correlation is small and cannot on the numbers dealt with be considered certainly significant, but it does seem to indicate that the problem of rickets and intelligence is worth considering on ampler material. It may be noted that none of the four mentally defective girls falls into class (3), i.e. that of definite evidence of rickets.

(xvii) *Summary of this Section on Ocular Characters and Intelligence.* Table CCLXIII provides the constants measuring the relation of the teachers' judgment of intelligence and of place in class with the various ocular characters we have recorded. The reader must carefully bear in mind the interpretation to be put on the term "non-significant," it signifies that the relationship, if any, is so slender that it cannot be brought to light on our data. This does not merely mean that association might be demonstrated on larger numbers, but it forcibly suggests that if found it would be of very small importance. A correlation which would have clinical or educational value, say one lying between ·4 and ·6, has in no case come to light, and our data are adequate in extent to bring it to light had it actually existed.

Not one of the coefficients of correlation has any prognostic value, with the possible exception of corneal astigmatism in the case of the observations of A and B only. We have, however, fully recognised that the coefficient of correlation may not be adequate, the relationship may be of a skew character, and accordingly not only has the correlation ratio been found, but wherever it seemed the least appropriate skew regression curves have been fitted to the plotted means.

The total result is that even allowing for *slight* relations found in the case of refraction class, and the corneal measurements, we must conclude on the basis of our records that defects of sight are not, as some have supposed, a *fundamenal* factor in determining educational dulness. Those who have emphasized slowness and dulness as arising from poor sight can hardly have based

their standard of slowness and dulness on other than the teachers' judgment of intelligence, and on success in school achievement as determined by place in class. We even venture to think that their records of mentality and achievement have scarcely been as copious or thorough as our own. That our records of mental characters are in no sense random in character has been shown by their intercorrelation with each other and with conscientiousness.

Table CCLXIII. *Association of Intelligence and Ocular Characters. General Table for Measures of Correlation.*

Characters	Correlation Coefficient	Correlation Ratio[1]
Place in Class and Visual Acuity (Binocular). Boys	$+\cdot0065 \pm \cdot0363$	—
Intelligence and Visual Acuity (Monocular). Boys	$+\cdot0093 \pm \cdot0214$	·1274
Intelligence and Visual Acuity (Binocular). Boys	—	Non-significant
Intelligence and Visual Acuity (Best Eye). Boys	$+\cdot0420 \pm \cdot0282$	·1552
Intelligence and Visual Acuity (Best Eye). Girls	—	·1395 (? significant)
Near Point and Intelligence. Boys	$+\cdot1250 \begin{cases} r_{t_1} = -\cdot0272 \pm \cdot0386 \\ r_{t_2} = +\cdot0330 \pm \cdot0387 \end{cases}$	Non-significant
Near Point and Place in Class. Boys	$+\cdot0479 \pm \cdot0276$	—
Refraction Class and Intelligence. Boys	$r_{t_1} = -\cdot1197 \pm \cdot0477$ $r_{t_2} = +\cdot0083 \pm \cdot0364$ $r_{t_3} = +\cdot1200 \pm \cdot0395$	$C_2' = \cdot2020$, but results very irregular and difficult of interpretation
Refraction Class and Place in Class. Boys	$r_t = -\cdot0349 \pm \cdot0449$	·1306
General Refraction and Intelligence. Boys	$r_t = -\cdot0049 \pm \cdot0372$	Non-significant
General Refraction and Place in Class. Boys	$-\cdot0027 \pm \cdot0255$	Non-significant
Corneal Refraction and Intelligence. Boys (A, B and C) ...	—	Non-significant
Corneal Refraction and Place in Class. Boys (A, B and C) ...	$-\cdot0045 \pm \cdot0242$	Non-significant
Corneal Refraction and Intelligence. Boys (A and B) ...	—	Non-significant
Corneal Refraction and Place in Class. Boys (A and B) ...	$-\cdot1331 \pm \cdot0361$	2359 (? significant)
General Astigmatism and Intelligence. Boys	—	Non-significant
General Astigmatism and Place in Class. Boys	$+\cdot0079 \pm \cdot0255$	Non-significant
Corneal Astigmatism and Intelligence. Boys (A, B and C) ...	$-\cdot0496 \pm \cdot0214$	Non-significant
Corneal Astigmatism and Place in Class. Boys (A, B and C)	$-\cdot0220 \pm \cdot0242$	Non-significant
Corneal Astigmatism and Intelligence. Boys (A and B) ...	$r_t = \cdot2090 \pm \cdot0536$	·1733
Corneal Astigmatism and Place in Class. Boys (A and B) ...	$+\cdot0974 \pm \cdot0365$	·2502
Appearance of Fundus and Intelligence	$r_t = \cdot0518 \pm \cdot0477$	—

[1] In all cases the correlation ratio is for Intelligence or for Place in Class on the Ocular Character. Where a numerical value for the correlation ratio is given it is significant or possibly significant.

On the other hand some readers may be inclined to assert that our ocular records are at fault. We should be the last to deny the extreme difficulty of our task in this respect; but here we would point out that the ophthalmic examination was far more protracted and thorough than that of the ordinary school medical examination, on which the usual statements as to the relation of mentality and sight have been made. Further, our Section C suffices to demonstrate that the ocular measurements have not been taken at random; their intercorrelations are quite significant, as they certainly would not have been had the non-significant character of the ocular traits with our measures of intelligence arisen from our ophthalmic determinations being idle. We think it more reasonable to hold that the grosser defects of Sight are now detected early in school life and remedy is found for them; they no longer, if they ever did, form a source from which stupidity and dulness arise. In saying this we do not deny the existence of mentally dull individuals with defect of vision. The fact is that in certain low types—generally the product of heredity—poor mentality is closely linked with poor physique, and this poor physique extends not only to the organs of perceptual judgment, but to the sensory organs. But because a small percentage of stupid children have poor sight, it by no means follows that a large amount of stupidity is a product of poor sight. As we have so often had occasion to proclaim, association in a few individuals does not mean organic correlation, still less a causation.

(To be continued)